



Detection of new variable stars in the SMC cluster NGC 121

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Abstract. New candidate variable stars have been identified in the Small Magellanic Cloud cluster NGC121, by applying both the image subtraction technique (ISIS, Alard 2000) and the Welch & Stetson (1993) detection method to HST WFPC2 archive and ACS proprietary images of the cluster. The new candidate variable stars are located from the cluster's Main Sequence up to Red Giant Branch. Twenty-seven of them fall on the cluster Horizontal Branch and are very likely RR Lyrae stars. They include the few RR Lyrae stars already discussed by Walker & Mack (1988). We also detected 20 Dwarf Cepheid candidates in the central region of NGC121. Our results confirm the “true” globular cluster nature of NGC121, a cluster that is at the young end of the Galactic globulars’ age range.

Key words. Globular Clusters: NGC121 — Variable Stars: RR Lyrae

1. Introduction

NGC121 is a key cluster to understand the Star Formation History (SFH) occurred in the SMC through the study of the similarities and differences with respect to the Milky Way clusters. In fact, with an estimated age of about 10 Gyrs, it locates at the transition between open and globular clusters in the MW. Moreover, as emphasized by Stryker et al. (1987), NGC121 very likely marks the boundary between “old” Population II (containing RR Lyrae but not

carbon stars) and intermediate-age populations (containing carbon stars but not RR Lyrae stars). Up to now, only four RR Lyrae stars with light curves derived from ground-based observations, were known in NGC121 (Walker & Mack 1988), and references therein). As part of a coordinated HST and ground-based effort, we have observed the SMC with the ACS (Cycle13, GO prog.10396, PI Gallagher), pointing at 7 star clusters of different age and metallicity (including NGC121) and 7 fields in various galactic locations (center, periphery, wing and bridge towards the LMC), to derive

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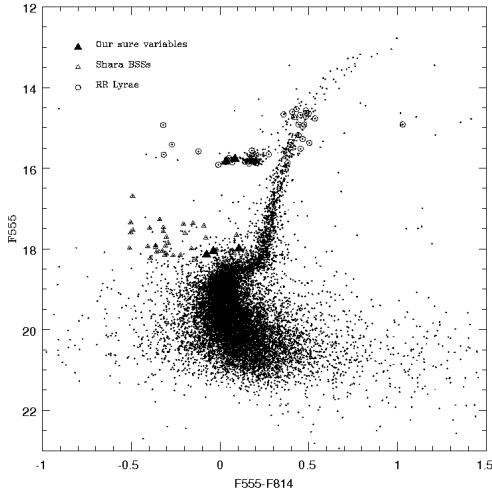


Fig. 1. CMD of NGC 121 for stars on the Planetary Camera (PC) of the WFPC2. Variable stars are marked by different symbols. *Open circles:* RR Lyrae stars; *Open triangles:* Dwarf Cepheids; *Filled triangles:* Sure variables.

their key evolution parameters and SF histories (see e.g. Glatt et al. 2007, submitted). The ACS observations of NGC121 were taken in time-series fashion in order to use them, along with the existing WFPC2 archive data of the cluster, to detect new variable stars in the cluster.

2. Observations and data reductions

The dataset used for our analysis consists of 18 images of NGC121 in the *V* (F555W) band and 12 images in the *I* (F814W) band, taken with the Wide Field Planetary Camera 2 (WFPC2, Dolphin et al. 2001) and with both the High-Resolution Camera (HRC) and the Wide Field Camera (WFC) of the Advanced Camera for Surveys (ACS) on board of the HST. The images cover temporal ranges of 2.5 (WFPC2), 0.35 (HRC) and 1.2 (WFC) hours in length, respectively. Since the primary goals of both proprietary and archive observations were to derive key stellar population parameters for the SMC, from the analysis of deep *V, I* color-magnitude diagrams, the observa-

tions generally consisted of a few deep images obtained with long exposure times. For these reasons our images, while still adequate to detect variable sources, are not adequate to derive periodicities for variables of RR Lyrae type, whose typical periods are in the range from 7 to 12-15 hours. Nevertheless, we succeeded to identify and build portions of the light curve for many new RR Lyrae star candidates, and we also detected for the first time several Dwarf Cepheids (DCs) in NGC121. The first data reduction was performed with the DAOPHOT/ALLSTAR/ALLFRAME package (Stetson 1987, 1994), but our best and deepest photometry was obtained with the Dolphot/HSTphot packages, implemented by Dolphin (2000, and reference therein) “ad hoc” to perform the photometry of WFPC2 and ACS images, respectively. An additional advantage of the Dolphot/HSTphot packages is to output the star magnitudes already calibrated in the Johnson-Cousins photometric system, making easier the study of the light curves of the candidate variables.

3. Variable star identification & conclusions

The NGC121 candidate variable stars were identified by applying both the image subtraction technique (ISIS, Alard 2000) and the Welch & Stetson (1993) detection method. We identified about 50 candidate variables in NGC121. Period search was performed using GRaTiS (Graphical Analyzer of Time Series) a private software developed at the Bologna Observatory (see e.g. Clementini et al. 2000). Twenty-seven of the candidate variables are located on the cluster Horizontal Branch, thus are very likely RR Lyrae stars. They include the few RR Lyrae stars already discussed by Walker & Mack (1988). We also detected 20 Dwarf Cepheid candidates in the central region of NGC121, and recovered 34 Blue Straggler star candidates found by Shara et al. (1998). DCs are late-A and early-F type stars, that populate the instability strip near or slightly above the zero-age main sequence and have magnitude from 0.2 to about 3 mag fainter than the RR Lyrae stars. In the CMD they fall where

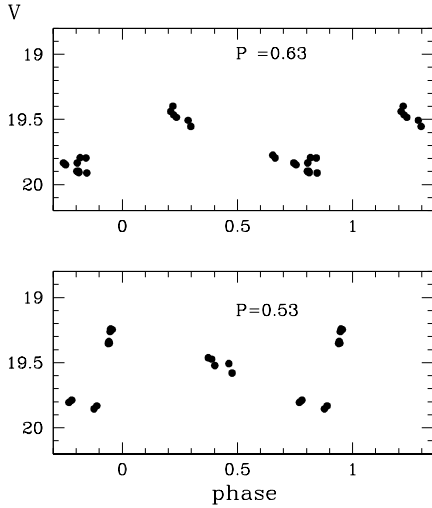


Fig. 2. Light curves of fundamental-mode RR Lyrae stars. *Upper panel:* new RR Lyrae star with $P \sim 0.63$ days. *Lower panel:* the fundamental-mode RR Lyrae star V37 discovered by Walker & Mack (1988).

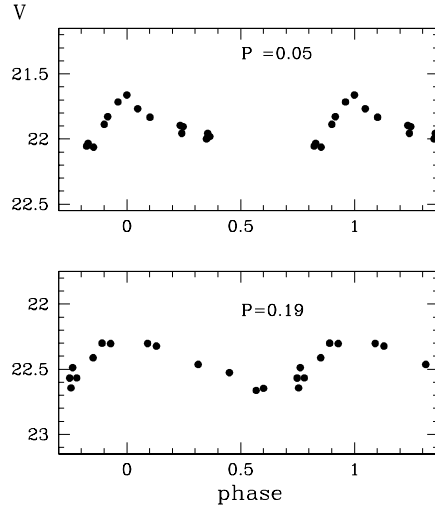


Fig. 3. Light curves of two Dwarf Cepheids. *Upper panel:* SX Phoenicis star with $P=0.05$ days. *Lower panel:* δ Scuti star with $P=0.19$ days.

the instability strip crosses the region of the Blue Straggler stars. These variables have typical periods in the range from 1 to 6 hours, thus our data sampling allow to sample their light curves better than for the RR Lyrae stars.

DCs are divided into: 1) δ Scuti stars, which are metal rich, young, Population I stars with typical periods longer than 0.1 day usually observed in open clusters and in the field of the MW; and 2) SX Phoenicis stars, which are metal poor, Population II variables, generally observed in GCs, with typical periods in the range from 0.03 to 0.09 days (Poretti et al. 2006). NGC121 seems to host both types of DCs. Fig. 1 shows the CMD of NGC121 for stars on the PC of the WFPC2, obtained using DAOPHOT/ALLFRAME for the data reduction. The variable stars are marked by different symbols (see caption). Examples of light curves for RR Lyrae stars and DCs are shown in Figs. 2-3.

The conspicuous number of RR Lyrae stars detected in NGC121 confirms the “true” globular cluster nature of NGC121, a cluster that is

at the young end of the Galactic globulars’ age range. The apparent presence of both δ Scuti and SX Phoenicis stars in NGC121 is an intriguing feature, that needs to be confirmed by a more detailed analysis of the light curves and a careful study of the contaminations by the SMC field stars.

References

- Alard, C., 2000, A&AS, 144, 363
- Clementini, G., et al. 2000, AJ, 120, 2054
- Dolphin, 2000, PASP, 112, 1383
- Poretti et al. 2006, MSAIt, 77, 219
- Walker, A., Mack, P., 1988, AJ, 96, 872
- Welch & Stetson, 1993, AJ, 105, 1813
- Shara et al., 1998, ApJ, 508, 570
- Stetson, P. B., 1987, PASP, 99, 191
- Stetson, P. B., 1994, PASP, 106, 250
- Stryker, L., 1987, nngp.proc, 10S